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UAVs and Photogrammetry

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ABSTRACT

The Unmanned Aerial Vehicle (UAV) is a remote-controlled aircraft. It can be operated remotely in real-time or pre-programmed to fly autonomously on the pre-defined routes. Popularly known as a drone, the use of this type of aircraft is increasing in all sectors. Within the last few years, UAVs have opened a new realm of opportunities for Surveying and Mapping, introduced better, faster, and cost-effective methods for the practice of Photogrammetry. In this paper, we discuss the evolution of Photogrammetry, the evolution of UAV, UAV in Geomatics, the impact of UAV in Photogrammetry, the current trend, and future implications.

1. INTRODUCTION

Photogrammetry is the art and science of determining the position and shape of objects from photographs (Kraus 1994). It has been in existence for quite a while now, and back in 1480, Leonardo da Vinci wrote the following: "Perspective is nothing else than the seeing of an object behind a sheet of glass, smooth and quite transparent, on the surface of which all the things may be marked that are behind this glass. All things transmit their images to the eye by pyramidal lines, and these pyramids are cut by the said glass. The nearer to the eye these are intersected, the smaller the image of their cause will appear." The principles of perspective and projective geometry form the basis from which photogrammetric theory is developed. However in the 19th century, precisely in 1849, Aime Laussedat, known as the father of Photogrammetry, was the first to use terrestrial photographs for topographic map compilation. He was also the first person to experiment with aerial photography using kites and balloons. It must be noted as well that Photogrammetry in America started with the military and world war. It is generally believed that there are two types of Photogrammetry namely Terrestrial and Aerial Photogrammetry. However, the development cycles are more than two. The developments in photogrammetry, from around 1850, have followed four development cycles (Konecny 1985). Each of these periods extended about fifty years. These cycles include: Plane table, Analog, Analytical and Digital Photogrammetry. The fourth cycle is still prevalent, and the use of UAVs is associated with it.

There is already an extensive scope for geomatics applications of Unmanned Aerial Vehicle (UAV) imagery. Some of the applications put into operation include archaeology, architecture, cultural heritage, large scale mapping, 3D city modeling, change detection in urban and suburban areas, cadastral mapping, agriculture and forestry, natural and man-made hazards, environmental and construction monitoring (Gruen 2012). This study aims to investigate the evolution of UAV and how it has impacted Photogrammetry.

2. METHOD

This study is based on literature review. Accessible journals, papers, and books on UAV and UAV photogrammetry have been examined. Relevant information, results and conclusions made have been included in the results section.

2.1. Evolution of Photogrammetry

Photogrammetry has witnessed massive evolution from the early 1900s till date.

In the early 1900s, before 1930, people had to walk the land and early map production was by foot (ASPRS 2009). In the 1930s, the Zeiss multiplex stereoplotter was created. In the 1940s, Bausch and Comb Multiplex stereoplotter and 5 lens camera system were produced. In the 1950s, Fairchild single lens camera and Kelsh stereoplotter were created. In the 1960s, Wild and Zeiss Cameras were created, as well as mechanical projection plotters. In the 1970s, Digital output on stereoplotter was created, low distortion lenses were made and LANDSAT came into being. In the 1980s, analytical stereoplotter, CADD based digital mapping and image

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motion compensation cameras were created. In the 1990s, softcopy photogrammetry, digital orthophotography, and digital cameras were all created. It was from this period that GIS got integrated in mapping and digital photogrammetry really took off.

Photogrammetry as we know, reached its apex of evolution because of the ability to digitize directly. Now anyone can access a map on their computers or mobile devices, the field has become ubiquitous (ASPRS 2009). In recent times, UAVs have taken the place of manned aircraft and are now used as platforms for sensors through which aerial photographs are captured.

2.2. Evolution of UAV

UAVs were first created and used in military applications where flight recognition in enemy areas, unmanned inspection, surveillance, reconnaissance and mapping of enemy areas without any risk for human pilots were the primary military aims (Nex and Remondino 2014). The earliest recorded use of a UAV dates back to 1849 when the Austrians attacked the Italian city of Venice using unmanned balloons that were loaded with explosives. Although balloons would not be considered a UAV today, this was a technology the Austrians had been developing for months before, which led to further advancements. In 1915, British military used aerial photography to their advantage in the Battle of Neuve Chapelle. They were able to capture more than 1,500 sky view maps of the German trench fortifications in the region.

The United States began developing UAV technology during the First World War in 1916 and created the first pilotless aircraft. Shortly after, the U.S Army built the Kettering Bug. While continuing to develop UAV technology, in 1930 the U.S Navy began experimenting with radio-controlled aircraft resulting in the creation of the Curtiss N2C-2 drone in 1937. During WWII, Reginald Denny created the first remote-controlled aircraft called the Radioplane OQ-2. This was the first massed produced UAV product in the U.S and was a breakthrough in manufacturing and supply drones for the military.

Drones were previously known to be an unreliable and an expensive toy, but in the 1980s this attitude began to change. The Israeli Air Force's victory over the Syrian Air Force in 1982 contributed to this change. Israel used both UAVs and manned aircraft to destroy a dozen of Syrian aircraft with minimal losses. Further, in the 1980s, The U.S created the Pioneer UAV Program to fulfill the need for inexpensive and unmanned aircraft for fleet operations. In 1986 a new drone was created from a joint project between the U.S and Israel. The drone was known as RQ2 Pioneer, which was a medium sized reconnaissance aircraft. More recently, in 1990 miniature and micro UAVs were introduced and in 2000 the U.S deployed the Predator drone in Afghanistan while searching for Osama Bin Laden. Although many of the most notable drone flights have been for military purposes, technology is continuing to advance and receive more attention. The term UAV is used commonly in the geomatics community, but also terms like Remotely Piloted Vehicle (RPV), Remotely Operated Aircraft (ROA), Remote Controlled (RC) Helicopter, Unmanned Vehicle Systems (UVS) and Model Helicopter are often used (Remondino et al. 2011). In terms of nomenclature, UAVs have had different names over the years, the most popular being drone.

Nowadays, UAVs are increasingly being used in civil and scientific research activities in different fields of application (Koeva et al. 2018). For example, for agriculture (Grenzdörffer and Niemeyer 2011), mapping (Nex and Remondino 2014), surveying and cadastral applications (Cunningham et al. 2011; Manyoky et al. 2011; Cramer et al. 2013; Barnes et al. 2014), archaeology and architecture (Chiabrando et al. 2011), geology (Eisenbeiss 2009), coastal management (Delacourt et al. 2009), disaster management (Choi and Lee 2011; Molina et al. 2012), damage mapping (Vertivel et al. 2015) and cultural heritage (Remondino et al. 2011; Rinaudo et al. 2012).

2.2.1. Uav and photogrammetry

The signs clearly point in the direction that the use of UAVs has been established, generally accepted, and vigorously growing (Lemmens 2015). Moreover, a group of experts on Global Geospatial Information Management has identified the increased demand for applying high-resolution imagery and the increase use of UAVs as a tool for rapid geospatial data collection as key emerging trends for the next ten years (UN-GGIM 2013).

The impact UAV has had on Photogrammetry is tremendous. This is evidenced by the number of papers that have been written within the past few years, and also by how much attention discussions around UAV receive in conferences. In 2004, the ISPRS congress in Istanbul hosted three UAS-related papers but did not feature any session specifically devoted to un-manned platforms (Colomina and Molina 2014). The trend changed in 2008, in Beijing, where 21 papers related to the use of UAS for Photogrammetry and Remote Sensing (PaRS) and mapping purposes were presented in three different sessions. At the ISPRS congress in Melbourne in 2012, nine sessions related to UAS were held, featuring around 50 UAS-related papers. The international photogrammetric community has set up a dedicated biennial conference that began in 2011: the UAV-g (UAV-g 2011 in Zürich, Switzerland, UAV-g 2013 in Rostock, Germany and UAV-g 2015 in Toronto, Canada). The increase in UAS related publications at these conferences is clear, yet not exclusive (Colomina and Molina 2014)

The IEEE Geoscience and Remote Sensing Society (IGARSS) has featured UAS-related papers at its annual symposiums since 2005. UAS-related papers have also been presented at the American Society for Photogrammetry and Remote Sensing (ASPRS) congresses, from 2005 in Baltimore up to present editions. Furthermore, the Multidisciplinary Digital Publishing Institute (MDPI) Open Access Journal of Remote Sensing published a special issue called "Unmanned Aerial Vehicles (UAVs) based Remote Sensing," closed in June 2012, with around 12 peer-reviewed papers (Colomina and Molina 2014). Since then, more papers have been written, and a lot more research has been carried out. The trend in drone research and applications is a continuing one which will still be effective many years from now.

3. RESULTS

In the last years, more and more applications of UAVs in the geomatics field became common (Remondino et al. 2011). UAV photogrammetry indeed opens various, new applications in the close-range aerial domain and introduces also a low-cost alternatives to the classical manned aerial photogrammetry (Colomina et al. 2008; Eisenbeiss 2009).

With photogrammetry it is possible to determine size, shape and location of depicted objects by measuring in images (Cramer 2001), this without a need of physical contact to the object (Linder 2009). Measurements can be performed using a single image, a stereo pair or in a block of two or more images (Cramer 2001). Measurements done in one image can only give 2D coordinates, while 3D coordinates can be obtained using two or more images of the same object, captured from different positions (Gustafsson and Zuna 2017). Different types of sensors including Light Imaging Detection and Ranging (LiDAR) and Radio Detection and Ranging (RADAR) can be mounted on UAVs and be used to capture geographic data which can be processed to form Orthophoto, Digital Terrain Model (DTM), Digital Surface Model (DSM), Digital Elevation Model (DEM), 3D model amongst others. The products that can be derived from aerial photographs captured through UAVs are applicable in diverse fields and not limited to photogrammetry alone. With the kind of software we have now, such as Agisoft photoscan and Pix4DMapper, processing aerial imagery can be done in a short time with the production of accurate models. This is faster and easier than using Analytical photogrammetry methods which included the rigorous least squares mathematical process and the use of stereoplotters. Some UAVs now come with inbuilt software that aid the processing of images captured.

4. DISCUSSION

Technically, UAVs can fly almost everywhere. Their flexibility is high and this fact allows them easily to change the observed location and viewing angle in a short time (Koeva et al. 2018). For that reason, it is important to pay attention to the safety of the users of aerial spaces, including manned or other unmanned aircraft, to the people and property on the ground, as well as their impact on the environment (Watts et al. 2012). This emerges from a concern regarding how this flying system, which does not have pilots on board, can be safely deployed in public space. With the ability to carry cameras, infrared sensors and facial recognition technology, they can present a serious threat to privacy. However, in daily practice, one obstacle is a missing or unfavourable regulatory framework. This is being controlled in many countries where UAVs are allowed to fly, for instance, China, Japan, U.S.A, and Sweden among other countries have strict regulations on where and how UAVs can fly, at what altitude and how long.

Although the battery life of UAVs is considered to be a drawback, provisions have been made to extend how long they remain in the air. Based on size, weight, endurance, range and flying altitude, UVS International defines three main categories of UAVs (Remondino et al. 2011), they are: (i) tactical UAVs which include micro, mini, close-, short-, medium-range, medium-range endurance, low altitude deep penetration, low altitude long endurance, medium altitude long endurance systems. The mass ranges from few kilograms up to 1,000 kg, the range from few kilometers up to 500 km, the flight altitude from few hundred meters to 5 km, and the endurance from some minutes to 2-3 days; (ii) strategical UAVs, including high altitude long endurance, stratospheric and exo-stratospheric systems which fly higher than 20,000 m altitude and have an endurance of 2-4 days; and (iii) special tasks UAVs like unmanned combat autonomous vehicles, lethal and decoys systems (Remondino et al. 2011). The primary airframe types are fixed and rotary wings while the most common launch/take-off methods are, beside the autonomous mode, air-, hand-, car/track-, canister-, bungee cord launched (Remondino et al. 2011). In any case, it is clear now that some types of UAVs can cover large areas since they can last more than two days. This shows that improvements have been made with specific UAVs which remove the drawback of them only being able to cover small areas because they do not last long in the air.

5. CONCLUSION

As opposed to the early 20th century when manned aircraft was the way aerial photographs were obtained, we now use UAVs/drones to capture images. The benefits that come with the use of UAVs are quite immense, for one; a reduced number of people are required during any flight operation thus making the process labour intensive. It is also a lot cheaper than the use of manned aircraft. These days, most drones come with inbuilt cameras and sensors which usually have high resolutions. In the event that other sensors are required, they can just be added to the drone as part of the payload. Not only do UAVs save money and reduce labour, they also consume less time. An operation that will take a week with the use of manned aircraft may take three days with UAVs. This is because flight planning can be done before reaching the site, also because drones can be set to fly autonomously.

UAVs will continue to thrive and grow in Photogrammetry not only because they offer cheaper and better options, but also because they are versatile and flexible. Producers of UAVs will continue to find ways around their limitations and therefore make them indispensable to Surveyors, Geomaticians and all other professions that currently use UAVs. İn a few years from now, manned aircrafts will not even be used anymore as platforms for capturing aerial photographs. UAVs are here to stay and they will continue to remain relevant in the field of Photogrammetry.

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